GEN. TMK #1

BXC-3986
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Lockheed Aircraft Corporation

ADVANCED DEVELOPMENT PROJECTS
BURBANK, CALIFORNIA

NRO REVIEW COMPLETED

REPORT NO. SP-404
DATE 7 Sept. 1962 (Revised)
COPY NO. 4

MODEL

TITLE FEASIBILITY REPORT, MODIFICATION OF A-12 VEHICLE FOR AIR LAUNCHED ORBITAL RECONNAISSANCE SYSTEM

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REVISIONS

DATE	PAGES AFFECTED

Approved For Release 2002/06/25 : CIA-RDP66B00762R000100060002-6

INTRODUCTION

This report is one of two which together discuss the feasibility of placing a reconnaissance system in orbit from an A-12 vehicle.

The following report, prepared by the Advanced Development Projects of the Lockheed California Company, is restricted to discussions of the A-12 aircraft as a launch vehicle. The other half of the study, relating to the reconnaissance payload, its orbiting vehicle, and the booster vehicle, is discussed in the Lockheed Missiles and Space Company Report SP 2-374.

The limitations in clearances of personnel in both companies have prevented consolidation of the two reports. Except in certain instances noted herein, the two reports have been satisfactorily integrated on a technical level.

I. SUMMARY

A. Purpose

The purpose of this report is to review the technical evaluation concerning the feasibility for utilization of an A-12 vehicle to launch an orbital reconnaissance vehicle over the Soviet land area. As a result of this preliminary evaluation, a configuration is recommended.

B. Configuration

Alternates were considered in the configuration of A-12 launch vehicle and booster. The following system is recommended:

1. Launch Vehicle

The basic A-12 vehicle proved satisfactory as a launch vehicle configuration. Modifications will enable the full altitude and speed capability of the A-12 to be utilized in the launching of the booster and payload. Utilization of maximum A-12 performance at launch minimizes the requirements for booster size. Changes required to the A-12 are provision for second crew member and the structural attachment of rails to the underside of the A-12 fuselage. This permits structural attachment, checkout, in-flight traverse and separation of the booster and payload. The existing A-12 or AF-12 subsystems possess the necessary power, cooling and supporting functions required by the booster and payload.

2. Booster System

The booster system selected is based on modification of the Polaris A3 and is described under Configuration "C" in LMSC Report SP 2-374. The modification consists of addition of a third booster stage and a payload section, with recovery capsule similar to current Agena/Discoverer. This system had been designed for injecting a payload in orbit from a submarine. With careful design, this booster can be attached to the underside of the A-12 with reasonable modifications.

C. Launch Vehicle Performance

The important performance parameters for the launch system are: Radius to Launch Area, Velocity at Booster Separation, Altitude and Attitude at Booster Separation. 25X1

The attitude of the booster is a function of launch vehicle attitude at separation, the booster system stabilization, and the time delay between separation and ignition.

A normal range of values is:

Cruise out 3.2M (2 Refuels)	2,340 n. mi.
Cruise out 0.8M	2,340 n. mi.
Attitude at Booster Separation	20° nose up
Velocity at Booster Separation	2.5M to 3.0M
Time from Separation to Ignition	5 seconds

II. DESCRIPTION - LAUNCH VEHICLE

The performance factors required for the subject mission required imparting to the missile an initial condition velocity vector, range for the required mission, and navigation and guidance systems which, in conjunction with the missile systems, provided satisfactory launch parameter accuracy.

Studies showed that the cruise drag of the combined missile/A-12 arrangement allowed adequate range with IFR and provided the required performance margin for launch. The two configurations studied were: (a) Missile carried on top of fuselage, (b) Missile carried beneath fuselage.

Considerations affecting the location of missile stowage ("over" vs. "under") were:

a. Delivery

1. Performance (velocity vector) at first stage ignition.

2. Safety.

b. Take-off performance

1. Ground clearance.

2. Nose gear unstick.

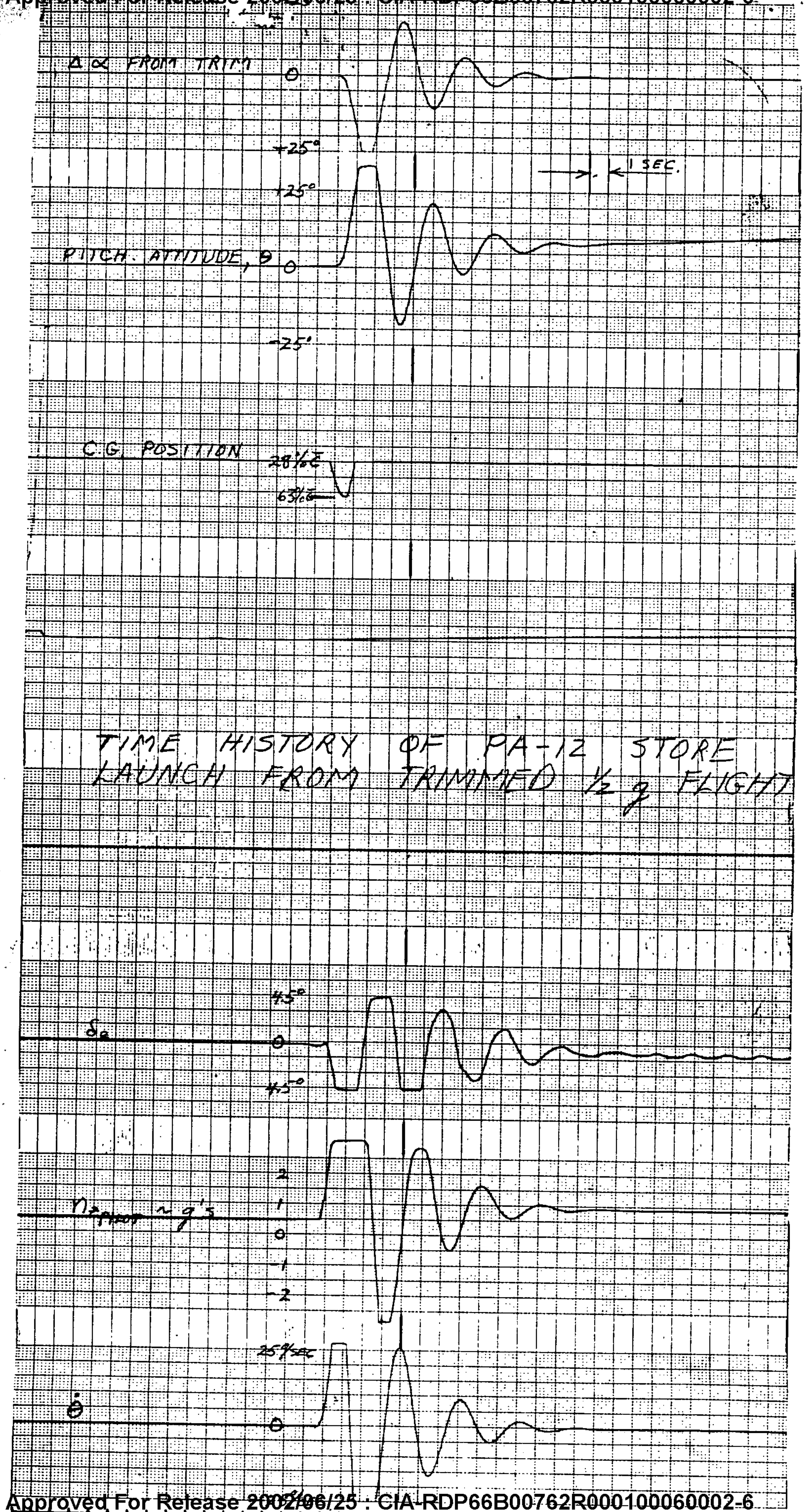
c. Cruise performance

1. Drag.

2. Stability and control.

d. Ground handling.

<u>"Over" Stowage</u>
Stowage on the upper fuselage (see Figure 1) is performed by sliding the missile onto a track. Separation is accomplished by extending a drag chute and pulling the missile aft. Assymetric fuselage loads require a severe structural beefup to support this concept.



TIME HISTORY OF PA-12 STORE LAUNCH FROM TRIMMED ½ g FLIGHT

Separation safety is considered much more critical, and additional separation pre-ignition timing degrades performance, compared to the belly launch.

The vehicle affects upper surface flow and reduces the predictability of the directional stability compared to the underside installation.

A study was made of the aircraft response during the launching of a Polaris missile from a track atop the A-12. It was assumed that the missile was launched by being pulled aft along rails from atop the A-12. A parachute deployed from the missile provided the pull.

As the missile slides aft, it moves the cg of the A-12 aft until, at disengagement, the A-12 cg is at 63%. This large instability, about 30% m.a.c., results in a very rapid pitch motion in response to any pitch disturbance. These motions result in positive or negative load factors on the A-12 sufficient to break the airplane. Ideally, this type of launch could be made a zero "g" load factor except that this maneuver cannot be made precisely enough to eliminate disturbances that would cause the airplane to diverge.

These studies were made using the A-12 simulator and a typical response is attached for a cruise condition laun ch with the airplane in a pitch over to 1/4 g. It is apparent that this launch procedure is not practical.

<u>Preferred Arrangement - "Under" Stowage</u>

The proposed installation is shown on Figure 2, "General Arrangement - AP-12."

The missile is secured on a track running along the bottom of the fuselage. The 421.6 in. length and 54 in. diameter permits one foot clearance with the gear and ground plane.

Some modifications to the landing gear will be required to allow full extension length with limited oleo compression during the taxi-takeoff condition and nose wheel lift off rotation.

The takeoff cg and gross weight are met by loading 50% fuel, and sequencing this to counterbalance the forward missile position required for takeoff and gear retraction.

The missile tail fairing is aft of the main gear for the takeoff position, with the same ground clearance angle used as on the A-12.

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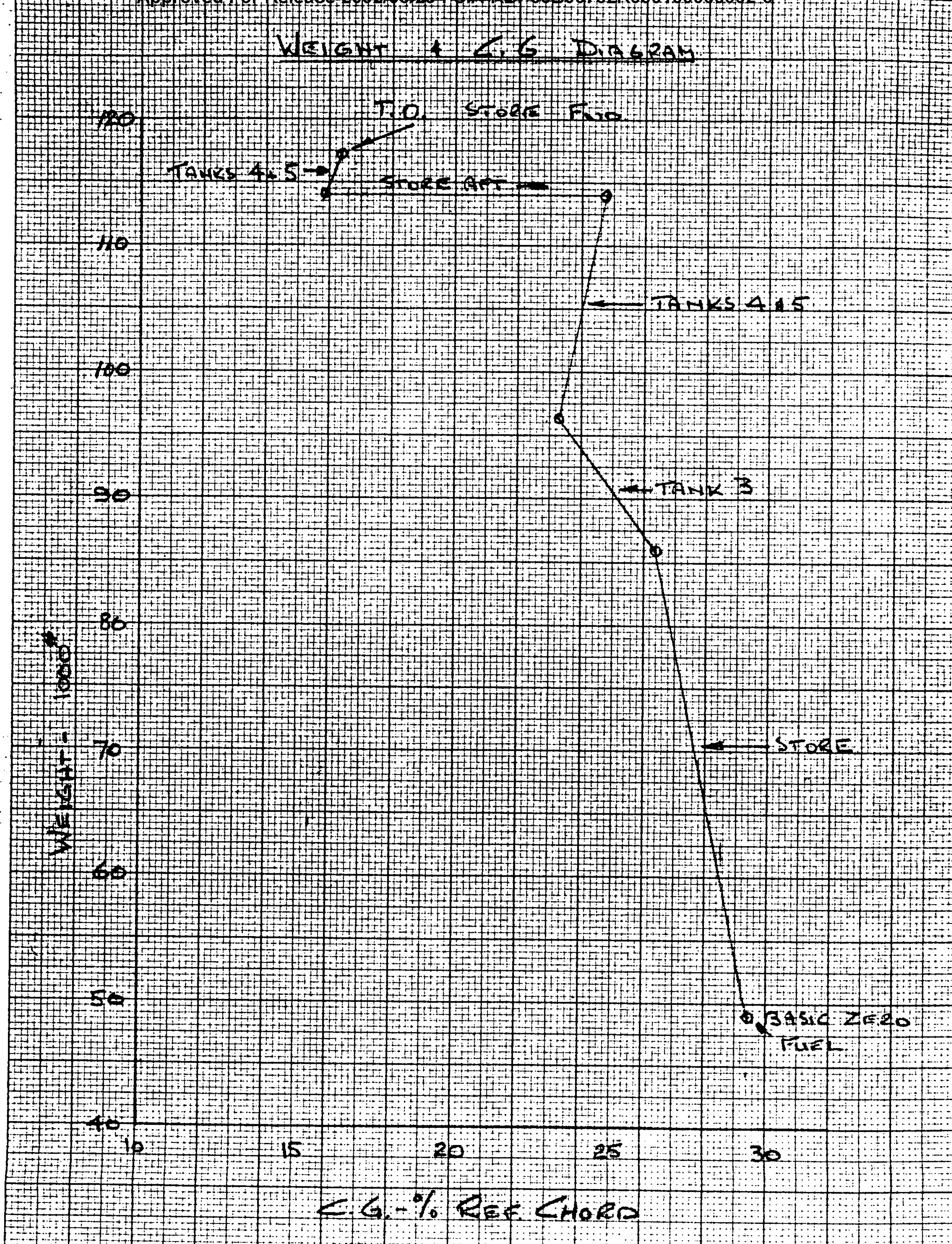

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The nose gear retracts forward of the missile, and the main gear and doors close between the missile and tail fairing, as shown. The tail fairing is moved aft to the cruise position along the fuselage track, and locked. The missile is shifted aft, while fuel transfer and stability augment compensate for trim change. The aft position is selected for optimum cruise longitudinal and directional stability condition.

The missile snugs into the fuselage/missile fairing and the boat tail is positioned into the tail fairing.

The above operation is reversible and can be checked out on the ground by removing the landing gear inner doors. All functions will then be validated in the cruise position, including seal adjustments, before returning to the takeoff position.

The underneath stowage arrangement allows for ready mating and ground checkout, safe separation and an improved cruise configuration. Performance parameters from launch to missile ignition are minimized with the stabilized missile drop procedure.

Design Data

The aircraft/missile combination at takeoff weighs 117,000 pounds, or the same as the A-12. 70,000 pounds of fuel are available after in-flight refueling, at a maximum flight weight of 141,500 pounds. Landing weight is 52,000 pounds.

Weight and balance of the aircraft plus missile, showing the missile shift, indicate an 8% aft movement with missile traverse.

The airplane is designed for a 2 g normal load factor, which will account for the mission design conditions.

Systems Description

Aircraft Guidance

Two transverse horizontal accelerometers are used as the basic sensor, i.e., to sense vehicle translations. These are mounted on a gyro stabilized platform in a configuration similar to that of a Schuler tuned system. The gyros required can have considerably less stringent requirements than those currently employed, however, as will be shown presently. Instead of relying on a long term gyro "memory", an additional pair of transverse horizontal accelerometers are used as first order vertical sensors.

In operation, the vertical sensing accelerometers operate only when acceleration rates are below some pre-established level. When the acceleration rates exceed this level, they are cut out of the level servo loop, and the vertical gyros provide a relatively short memory capability until such time that the acceleration rates again fall to below the cut-out level. As long as the accelerations remain nearly constant, they act in the servo loop to drive the platform to null their outputs. The other set of accelerometers remain in a circuit where their outputs are integrated to provide velocities and departures from the point of takeoff. While it is possible that a single set of accelerometers may be used for both functions, the use of two sets greatly simplifies the switching requirements.

With such an arrangement, the platform vertical is constantly upgraded by locally sensing the gravity vector. This greatly simplifies the computer requirements, since no memorized references are carried forward. The only continuous function required of the computer is the accrual of departures from takeoff, and even if this is lost it can be reestablished by correcting position to the coordinates of a known fix.

Accelerometers similar to those used in existing systems may be used both for the level sensors and for the displacement sensors. For level sensing, an accelerometer threshold of only 10^{-3} g can establish verticability to about 6.5 seconds of arc.

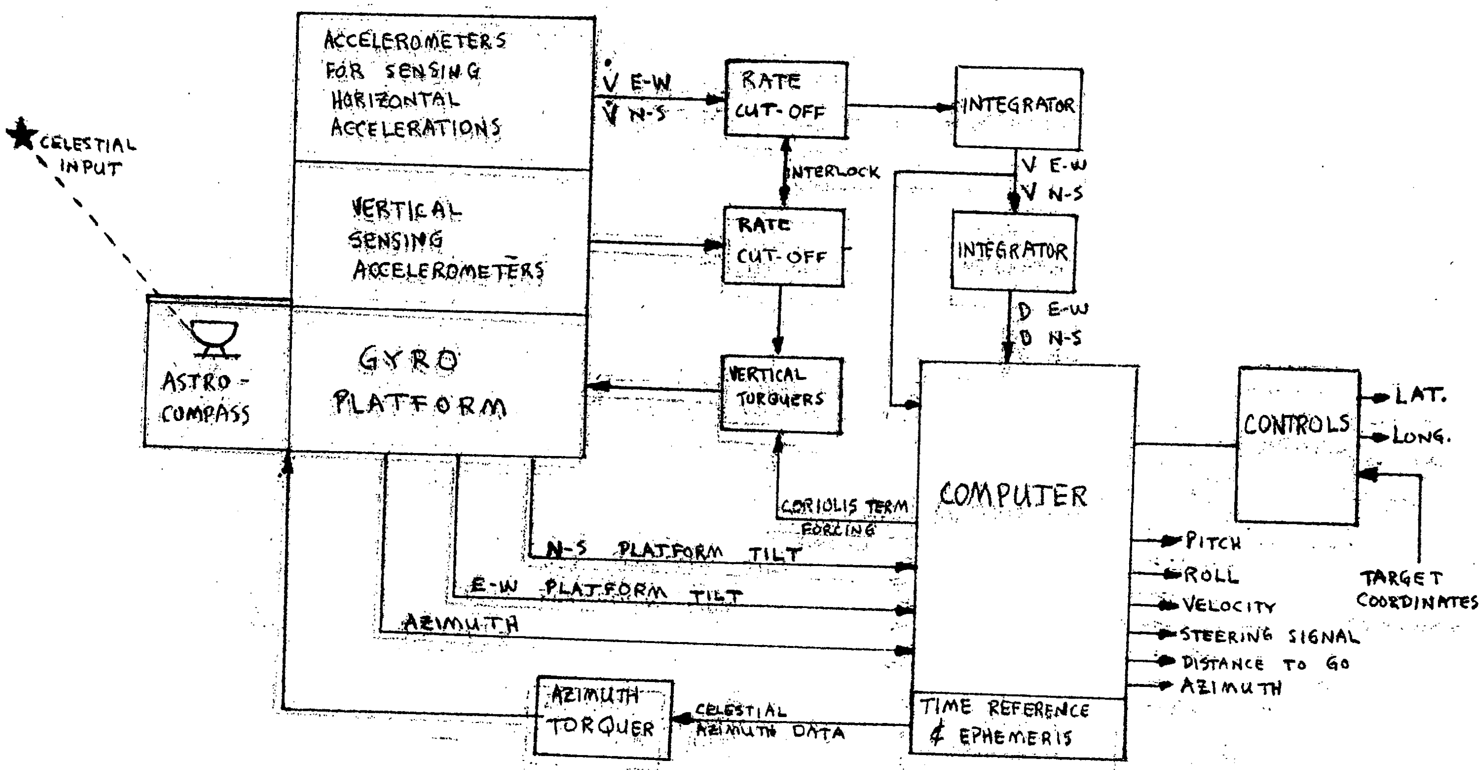
$$\text{Sin } 6.5'' \times 32 \cong 3.141 \times 10^{-5} \times 32 \cong 10^{-3}$$

Obviously the 10^{-4} g accelerometers in use on the present systems are more than adequate.

Gyro requirements are considerably more modest than those currently used, since the "memory" necessary can be very short. It is doubtful that the platform will ever be in pure gyro mode more than a few minutes at a time before flight conditions permit the level accelerometers to sense a new local vertical. Platform drift with a 0.1°/hr. drift gyro is at a rate of 1 arc minute in ten minutes.

To provide a degree of azimuth accuracy compatible with the vertical accuracy anticipated, a first order azimuth reference must be provided. This may be achieved most readily by slaving the azimuth channel to an astro compass.

The resolution of celestial sensors today is on the order of 7 sec. arc. With errors added when transferred through pickoff devices and a servo loop to drive the platform to the desired orientation, this may be degraded to as much as 30 sec. arc. The limiting factors then are not the sensors but occur in data transfer; hence it is not necessary or



BLOCK DIAGRAM - PROPOSED SYSTEM

logical to employ a sensor of maximum resolution. A resolution close to 20 sec. arc, therefore, will not degrade the accuracy enough to warrant use of one with higher resolution. This is particularly true in this system, where the inputs continuously update the alignment and orientation. With such a system, this becomes a bounded error which does not expand with time.

Since this is essentially a first order system, except during brief periods when the directly sensed inputs are not available and it is operating on gyro "memory", reaction time is greatly reduced. In fact, if a precise fix can be established in flight, the ground warm-up, alignment, and stabilization can be virtually eliminated.

While a measure of component interdependency and system vulnerability still exist, the greatly simplified computer requirements reduce this appreciably. In addition, failures in certain components will degrade accuracy but should not render the system inoperative. There is the further problem of aligning the booster guidance system to this system prior to launch.

The proposed system does not require development of any new or unknown techniques, and no new components are required. Using currently developed components and established techniques, the only development required is in their combination in a unique configuration.

The figure is a block diagram of the proposed system.

Autopilot

The basic stability augmentation system and autopilot developed for and used in the A-12 will serve for the AP-12 mission. The basic stability augmentation requirements are not significantly affected by the addition of the modified Polaris missile to the aircraft. Some minor gain changes may be desirable, but they will be within the capability of the system.

The present autopilot modes will provide sufficient pilot backup for this mission. The launch maneuver will not require autopilot programming. This maneuver requires a pullup from level Mach 3.2 flight at 70,000 to 75,000 ft. altitude at a load factor of 2 g until a flight path angle of 10^{o} to 15^{o} from horizontal is obtained. The launch conditions are most sensitive to heading, flight path angle, and speed. However, normal piloting techniques will position the system well within the tolerance requirements at launch to achieve the required orbit. For example, tolerances on heading are $\pm 5^{\circ}$ and on flight path angles are $\pm 3^{\circ}$. Launch requirements are not sensitive to position along the required heading or to launch altitude.

Missile Stowage and Launch Provisions

a. A group of hooks for missile support (three stations) and integral release to the free fall.

b. Fairings for the missile/aircraft fillet and an aerodynamic fairing for the missile boat tail.

c. A track for missile traverse from the ground position to the cruise/launch position. Traverse power is supplied by a rack and pinion arrangement.

d. A separable, expendable cooling jacket for missile case cooling under high speed cruise conditions.

e. An extendable leaf tail flare for missile stabilization. This is jettisoned at ignition.

f. Cooling and electrical connections are stowed within the joint fairing lines.

Aircraft Support Systems

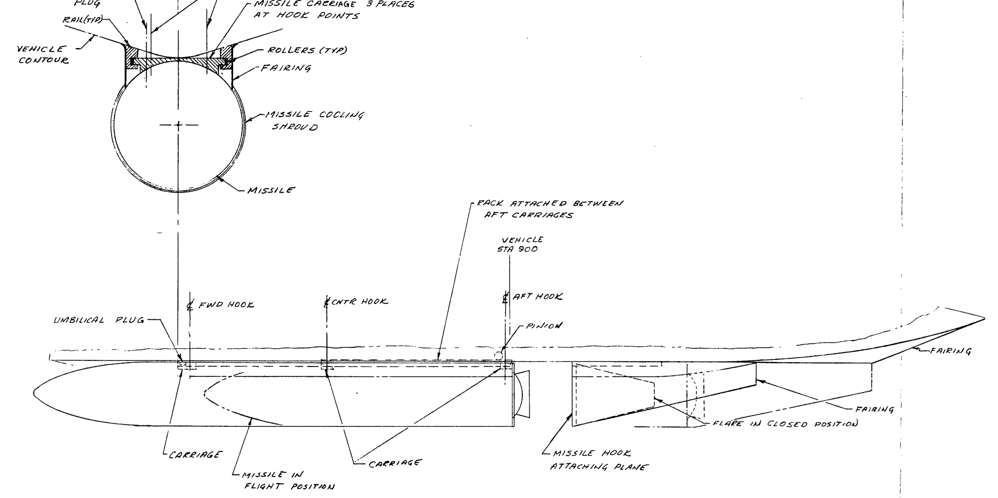
The aircraft and missile cooling load will be supplied from an air cycle system similar to that of the A-12 or, if necessary, a scaled down AF-12 liquid cooling system.

The balance of the aircraft systems are similar to those of the A-12 or AF-12. The rear cockpit is used, with suitable control/displays to perform the navigation, approach and separation maneuvers.

Miscellaneous

An electrical umbilical will be provided to mate with the orbital vehicle for power and signal transfer to the launch vehicle. Inasmuch as the missile operates entirely on a pre-programmed flight routine, no further communication with the orbital vehicle is necessary. A cooling connection is provided to supply cooling air from the launch vehicle to the third stage vehicle.

As noted in drawings, the missile is attached at three missile stations by engaging two hooks at each station. The hooks are attached to three carriages supported on two rails. The rack for retracting the missile aft is supported between the two aft carriages and is driven by a pinion from the launch vehicle. Separation occurs [illegible]



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MFG. & FINISH PER LAC PROCESS SPEC. 100	MISSILE "C" STORAGE PROVISIONS	NO. REQ / MODEL / NEXT ASSEM — REQUIREMENTS PER SHIP
TOLERANCES EXCEPT AS NOTED .XX = ± .03 .XXX = ± .010		DRAWN [redacted]
SCALE 1/20 & 1/40		STRESS / MAT'L / APPD. / CHG. LET.

AP-12 CHARACTERISTICS

WING	
AREA	$1795\ FT^2$
ASPECT RATIO	1.939
ROOT CHORD	60.833' (730.00")
TIP CHORD	0
SPAN	55.617' (667.40")
DIHEDRAL	0°
INCIDENCE (NEGATIVE)	-1° 12' 0"
AIRFOIL-MOD BI-CONVEX	2.5 %
SWEEP @ .25C	52° 37' 44.658"
M.A.C @ WS 118.0	40.555' (486.66")
ELEVON-INB'D	
AREA-EACH	$39.0\ FT^2$
TRAVEL	35° UP 20° DOWN
ELEVON-OUTB'D	
AREA-EACH	$52.5\ FT^2$
TRAVEL	35° UP 20° DOWN
VERTICAL TAIL-TOTAL	
AREA-EACH	$150.76\ FT^2$
ASPECT RATIO	.778
TAPER RATIO	.392
ROOT CHORD	20.00' (240.00")
TIP CHORD	7.833' (94.00")
SPAN	10.833' (130.00")
AIRFOIL-MOD BI-CONVEX	2.5 %
SWEEP @ .25C	32° 12' 2.53"
MAC. @ FIN STA 55.5289	14.80' (177.66")
VERTICAL TAIL-MOVABLE	
AREA-EACH	$70.24\ FT^2$
ROOT CHORD	14.80' (177.637")
TIP CHORD	7.833' (94.00")
MAC @ FIN STA 88.942	11.676' (140.111")
SPAN	6.206' (74.471")
TRAVEL	±20°
FUSELAGE	
DIAMETER	64.00"
OVERALL LENGTH	98.75' (1185.00")
WEIGHTS	
TAKEOFF WGT	117,000#
LANDING WGT	53,000#
MISSILE WGT	36,700#

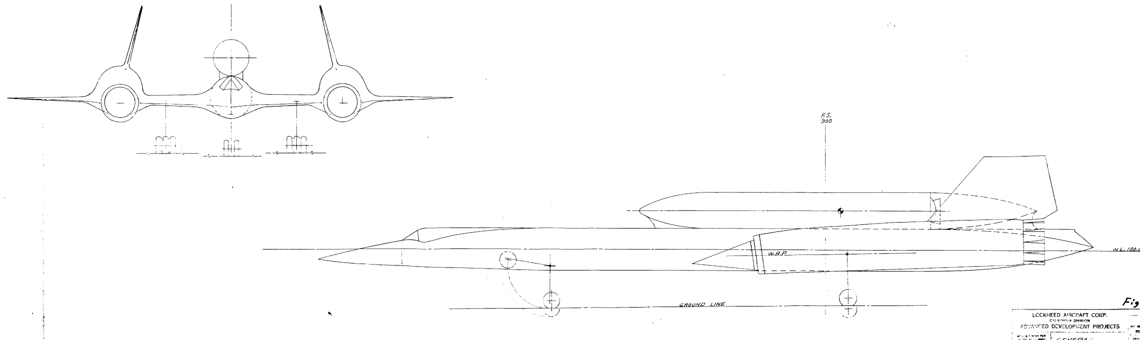

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Fig. 1

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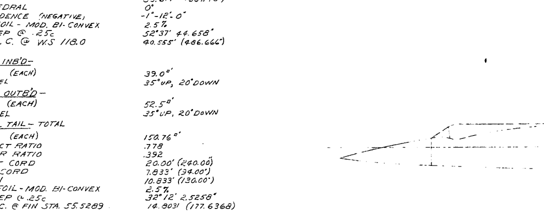
GENERAL
ARRANGEMENT
ALTERNATE
AP-12

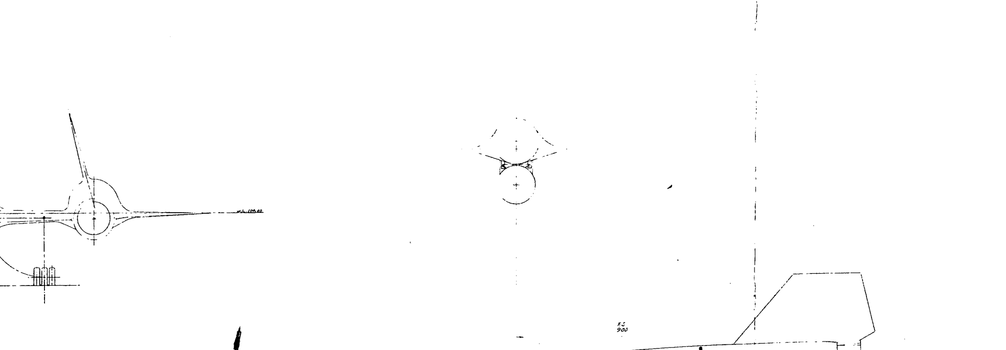
GA-AP-12

1/40

WING —	
AREA	1795□'
ASPECT RATIO	1.939
ROOT CORD	60.833' (730.00")
TIP CORD	0
SPAN	55.617' (667.40")
DIHEDRAL	0°
INCIDENCE (NEGATIVE)	-1°-12'-0"
AIRFOIL - MOD. BI-CONVEX	2.5%
SWEEP @ .25c	52°37' 44.658"
M. A. C. @ W.S 118.0	40.555' (486.666")
ELEVON - INB'D -	
AREA (EACH)	39.0□'
TRAVEL	35° UP, 20° DOWN
ELEVON - OUTB'D -	
AREA (EACH)	52.5□'
TRAVEL	35° UP, 20° DOWN
VERTICAL TAIL — TOTAL	
AREA (EACH)	150.76□'
ASPECT RATIO	.778
TAPER RATIO	.392
ROOT CORD	20.00' (240.00")
TIP CORD	7.833' (94.00")
SPAN	10.833' (130.00")
AIRFOIL - MOD. BI-CONVEX	2.5%
SWEEP @ .25c	32°12' 2.5258"
M.A.C. @ FIN STA. 55.5289	14.8031 (177.6368)
VERTICAL TAIL — MOVABLE	
AREA (EACH)	70.24□'
ROOT CORD	14.803' (177.637")
TIP CORD	7.833' (94.00")
MAC. @ FIN STA. 88.942	11.676' (140.111)
SPAN	6.206' (74.471)
TRAVEL	± 20°
FUSELAGE —	
DIAMETER	64.00"
OVERALL LENGTH	98.75' (1185.00")
WEIGHTS —	
TAKE OFF WGT.	117,000#
LANDING WGT.	53,000#
[illegible]	[illegible]

MISSILE POSITION IN FLIGHT





MISSILE POSITION FOR TAKE OFF

FIG. #2

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LOCKHEED AIRCRAFT CORP. CALIFORNIA DIVISION ADVANCED DEVELOPMENT PROJECTS	
GENERAL ARRANGEMENT AP12	GA-AP12
SCALE 1/40	

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A base plate is attached to the aft end of the basic missile, which engages the tail fairing section mounted aft of the launch vehicle landing gear by means of spring loaded hooks. The flaring mechanism (inverted umbrella) contained in the tail fairing section is spring loaded in the "faired" or retracted position. A fraction of a second after separation, an electrical signal from the missile is programmed to initiate a pyrotechnic device to deploy the umbrella. Electrical connection is made through the missile base plate. At first motor ignition, the entire tail assembly is jettisoned, including the attached base plate, by means of a pyrotechnic device.

III. PERFORMANCE

A. Launch

1. Launch Parameters

The best target launch condition is a compromise between the carrier capability in terms of flight path angle, load factor and Mach number, and the missile performance in terms of altitude and payload in orbit. One basic cutoff point is a minimum orbit altitude of 80 n. mi. Below this altitude, the orbit vehicle performance is compromised by the atmosphere. A second cutoff point is the maximum flight path angle that can be achieved by the carrier at the launch point. This angle decreases with increasing Mach number and is limited by the 2.0 g load factor capability of aircraft and missile. For example, the maximum flight path angle at Mach 3.2 is about 15°, increasing to more than 20° at Mach 2.5. Conversely, orbit altitude decreases with decreasing flight path angle at launch.

A study of conditions based on one post ignition missile guidance program indicates that, within these limitations, a payload of 900 to 1,000 pounds can be placed in an 80 n. mi. orbit for carrier launch speeds between Mach 2.5 and 3.0. These studies are being continued to determine the best post launch missile guidance program to place the maximum payload in orbit. It is apparent from the analysis which has been done that there is a substantial array of parameters acceptable to both carrier and missile that will place payloads of 900 pounds or more in orbits of 80 n. mi. or higher.

2. Carrier Maneuver Performance and Escape

The launch maneuver is primarily a 2 g pullup from a high speed level flight condition. The objective is to obtain the highest flight path angle consistent with normal piloting techniques and flight safety. The escape maneuver after launch is a 2 g rollout from the pullup to increase lateral separation, as well as vertical separation between the missile and aircraft. At ignition, the vertical and lateral separation will each be in excess of 500 feet.

3. Separation

Studies of means for stabilizing the aerodynamically unstable Polaris during the launch phase to ignition indicate that a skirt attached to the tail fairing can be expanded upon launch to provide a positive static margin of one diameter. This device is shown on Figure 3.

Alternates considered to provide the compensating moment to balance the two caliber unstable vehicle included fins and a drag chute.

The necessary drag chute would be approximately 16 feet in diameter and provide a 1 g drag force in order to generate the stabilizing moment. This method degrades launch performance in that 160 fps velocity is lost in five seconds of free fall and a three degree of flight path angle. This is equivalent to approximately 70 pounds of payload in the design launch regime.

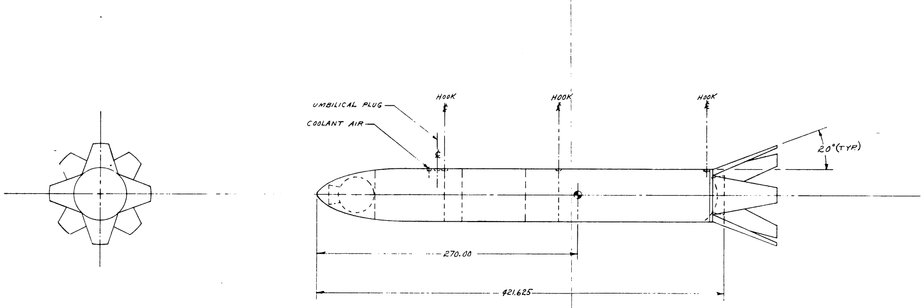
Tail fin stabilizing devices, although representing a low drag contribution for the balancing moment obtained, introduced a stowage problem for the cruise condition and a more complex mechanization, assuming fins stowed within the tail fairing.

The extendable tail flare selected results in a decelerative force of 0.3 g during launch and would result in a speed loss during the 5 second missile free fall of 50 feet per second. This is equivalent to .05 Mach. The tail fairing and skirt are separated at missile ignition.

Vertical separation between the missile and the aircraft at ignition will be greater than 500 feet. The flight path angle of the missile at ignition will be 1.5° less than at the time of launch.

B. Cruise Performance

The AP-12 performance is based directly on A-12 performance capability corrected for the additional drag and weight of the external missile. Missile drag increments are taken from Polaris wind tunnel data. Mach 3.2 and a subsonic mission are shown



MISSILE SHOWN IN STABILIZED FLIGHT PRIOR TO FIRST STAGE IGNITION

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Fig. 3

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MFG. & FINISH PER LAC PROCESS SPEC. 100	MISSILE CONFIG. "C"	NO. REQ. / MODEL / NEXT ASSEM — REQUIREMENTS PER SHIP
TOLERANCES EXCEPT AS NOTED .XX = ± .03 .XXX = ± .010		DRAWN [redacted] STRESS MAT'L APP'D. CHG. LET.
SCALE 1/40		

on Figures 4 and 5. Both missions are based on takeoff from a secure inland U.S. base and a missile launch point several hundred miles east of Hawaii. Initial takeoff is with partial fuel to keep airplane taxi and takeoff loads at a reasonable level. The airplane climbs to 25,000 feet and is refueled to 141,500 pounds. The second refueling operation occurs over the mid Pacific. Following this operation, the airplane cruises to the launch point and launches the missile at 80,000 feet at Mach 3.1. Fuel allowance is made for a 360° turn at the launch altitude and speed. Following the launch, the airplane descends toward the alternate field in Hawaii to a rendezvous with a tanker.

The return leg to the takeoff point is by supersonic high altitude cruise for both missions.

Fuel reserves at the mid ocean refueling point are about 8,000 pounds, and the fuel aboard at the post launch refuel point is sufficient to make an alternate field in Hawaii with 3,000 pounds reserve.

MISSION SUMMARIES

M = 3.2 Cruise Out	Weight Range	Altitude Range	Time Increment
Takeoff and Climb to Start Refueling over Base	100,000	4,500 - 25,000	- - -
Climbout, Cruise and Descend to Refuel	141,500-93,700	25 - 78,000	59 min.
Reserve Fuel........ 7,600 lbs.			
Climb and Cruise to Launch Point	141,500-97,500	25 - 80,000	46 min.
Climb, Cruise and Descend to Home Base	118,000-74,100	25 - 90,000	95 min.
Reserve Fuel at Home Base......... 24,700 lbs.			
Reserve Fuel at Alternate Base....... 3,000 lbs.			

M = 0.8 Cruise Out	Weight Range	Altitude Range	Time Increment
Takeoff and Climb to Start Refueling over Base	100,000	4,500 - 25,000	- - -
Cruise Out to 2nd Refueling	141,500-94,600	25 - 35,000	158 min.
Reserve Fuel......... 8,500 lbs.			
Cruise and Climb to Launch	141,500-97,500	25 - 80,000	107 min.
Climb, Cruise at M = 3.2 and Descend to Home Base	118,000-74,100	25 - 90,000	95 min.
Reserve Fuel at Home Base.......... 24,700 lbs.			
Reserve Fuel at Alternate Base........ 3,000 lbs.			

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PA-12

CRUISE OUT AT M=3.2

36,700 # LAUNCH PAYLOAD

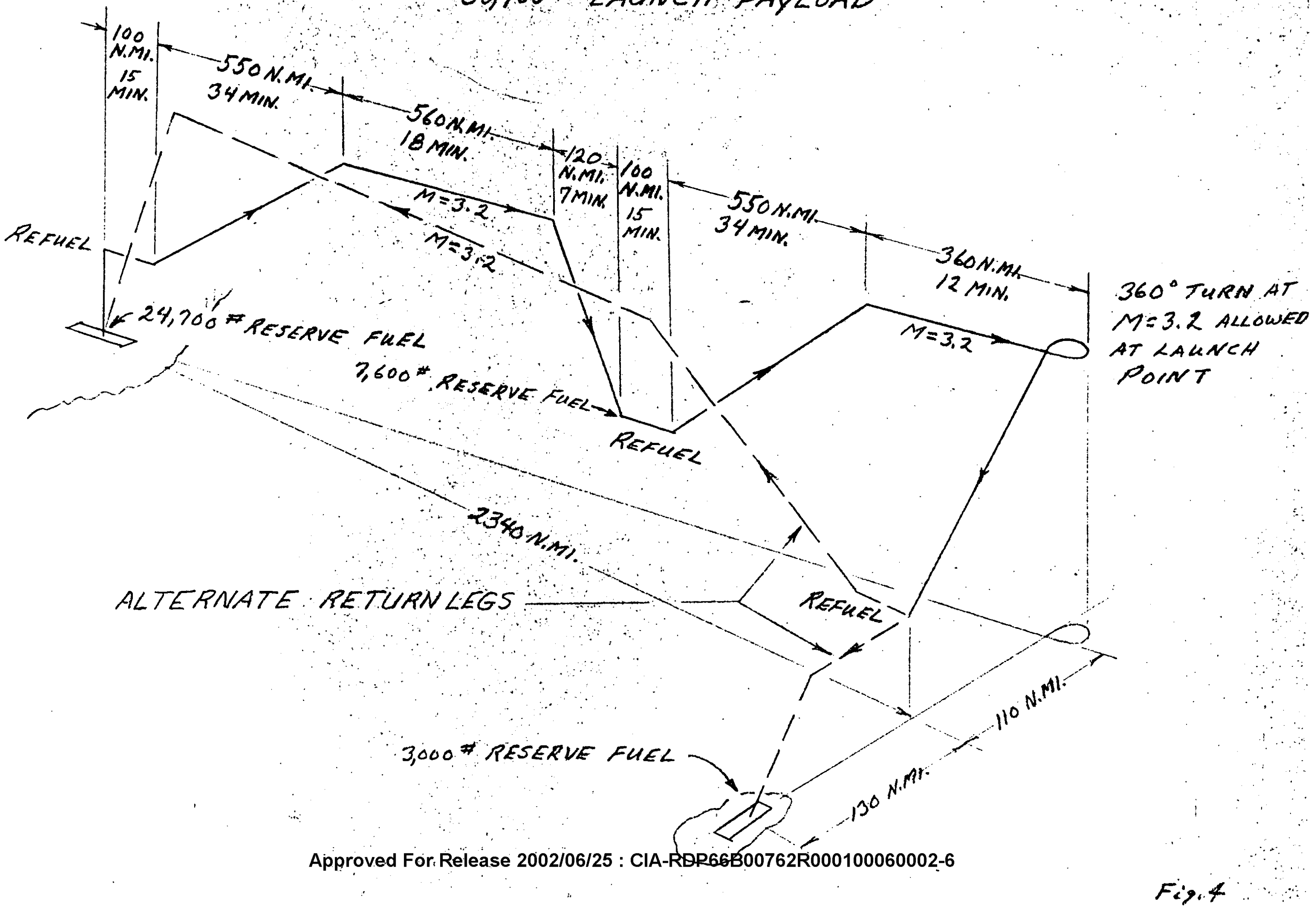

Fig. 4

PA-12

CRUISE OUT AT M=0.8

36,700 # LAUNCH PAYLOAD

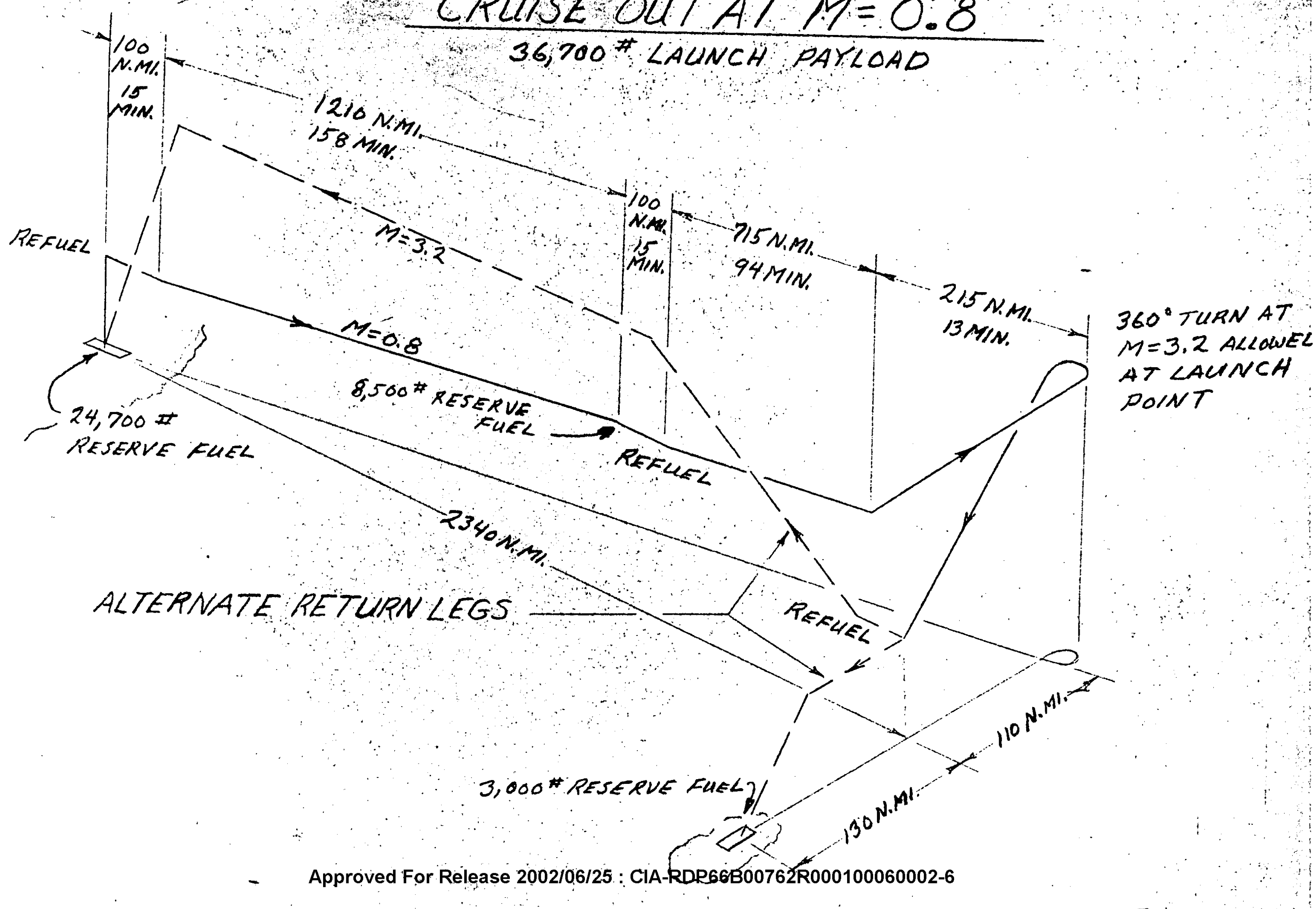

Fig. 5